FIG.1A

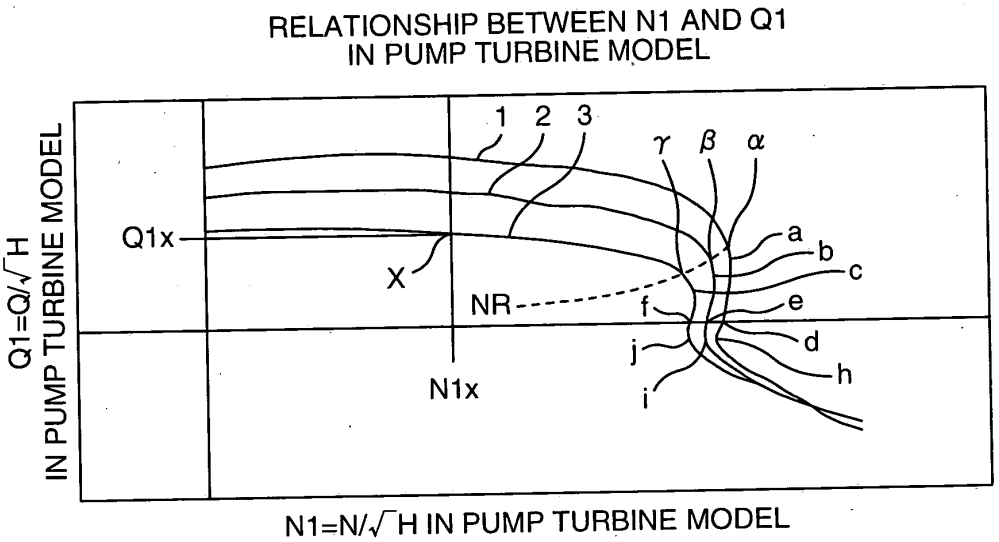

RELATIONSHIP BETWEEN N1 AND Q1
IN PUMP TURBINE MODEL
Q1=Q/√H
IN PUMP TURBINE MODEL
1 2 3
γ β α
Q1x
X
a
b
c
NR
f
e
d
j
h
i
N1x
N1=N/√H IN PUMP TURBINE MODEL

FIG.1B

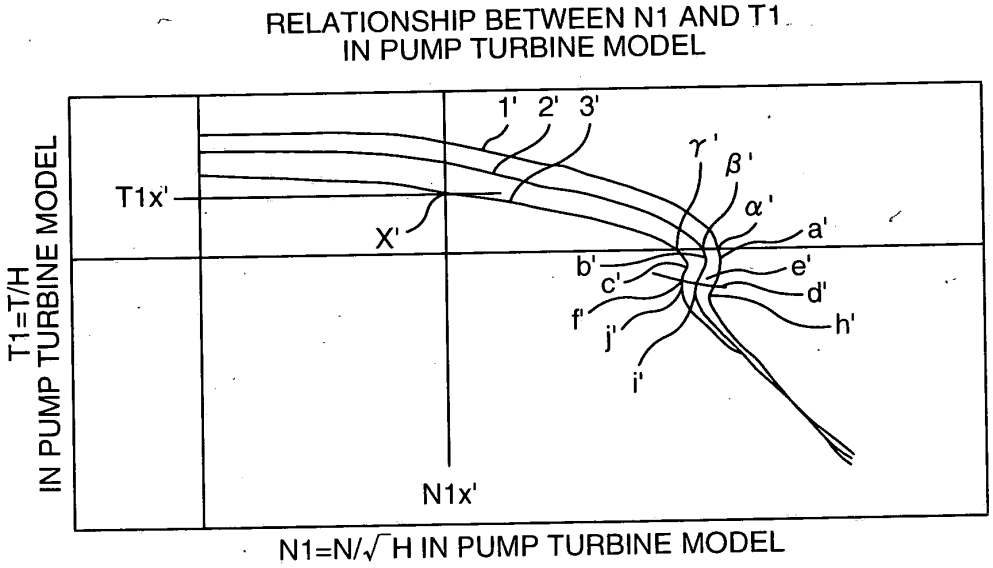
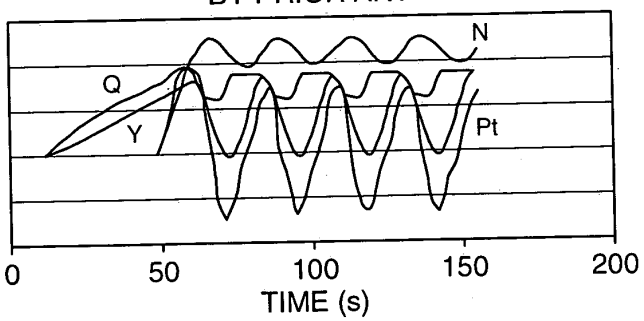
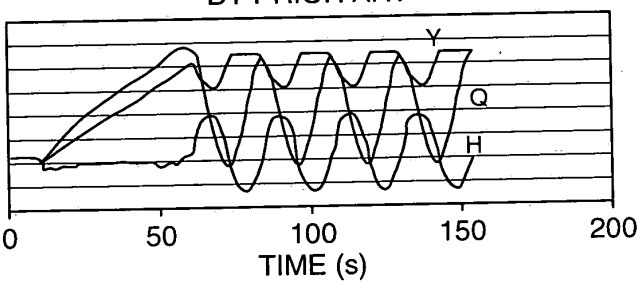

RELATIONSHIP BETWEEN N1 AND T1
IN PUMP TURBINE MODEL
T1=T/H
IN PUMP TURBINE MODEL
1' 2' 3'
γ' β'
T1x'
α'
X'
a'
b'
e'
c'
d'
f'
h'
j'
i'
N1x'
N1=N/√H IN PUMP TURBINE MODEL

FIG.2

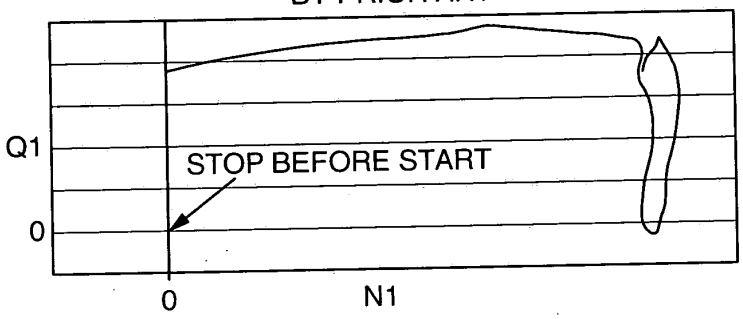
START IN S-CHARACTERISTIC PORTION
BY PRIOR ART



START IN S-CHARACTERISTIC PORTION
BY PRIOR ART



START IN S-CHARACTERISTIC PORTION
BY PRIOR ART



START IN S-CHARACTERISTIC PORTION
BY PRIOR ART

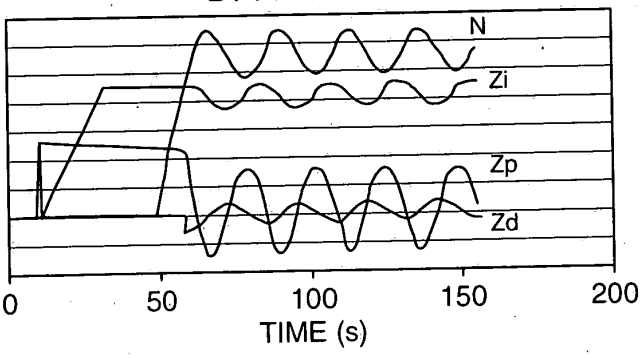


FIG.3

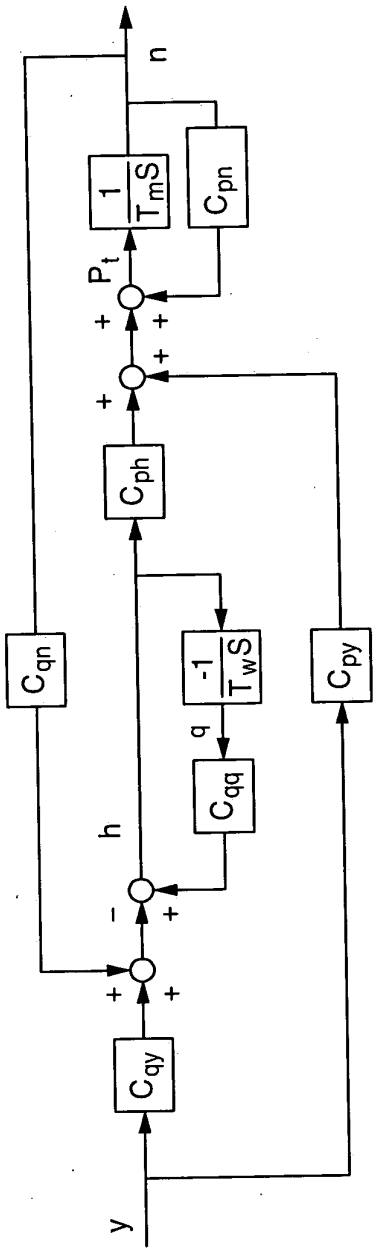

n
$\frac{1}{T_m S}$
C_{pn}
P_t
C_{ph}
C_{qn}
$\frac{-1}{T_w S}$
C_{py}
q
C_{qq}
h
C_{qy}
y

FIG.4

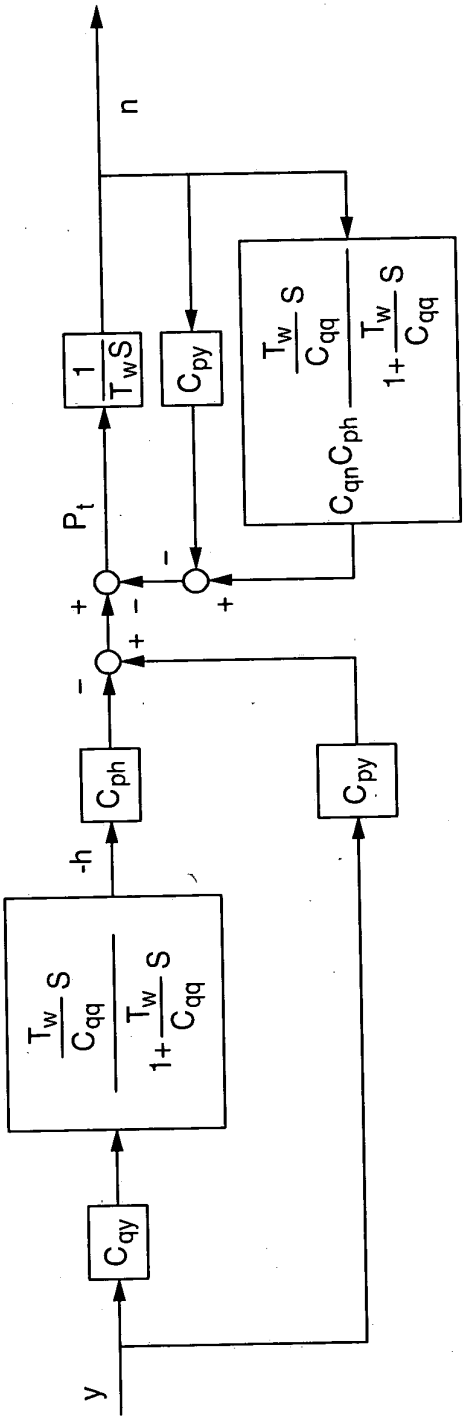

n
$\frac{1}{T_w S}$
C_{py}
$\frac{\frac{T_w}{C_{qq}} S}{C_{qn} C_{ph} - 1 + \frac{T_w}{C_{qq}} S}$
P_t
C_{ph}
C_{py}
-h
$\frac{\frac{T_w}{C_{qq}} S}{1 + \frac{T_w}{C_{qq}} S}$
C_{qy}
y

FIG.5

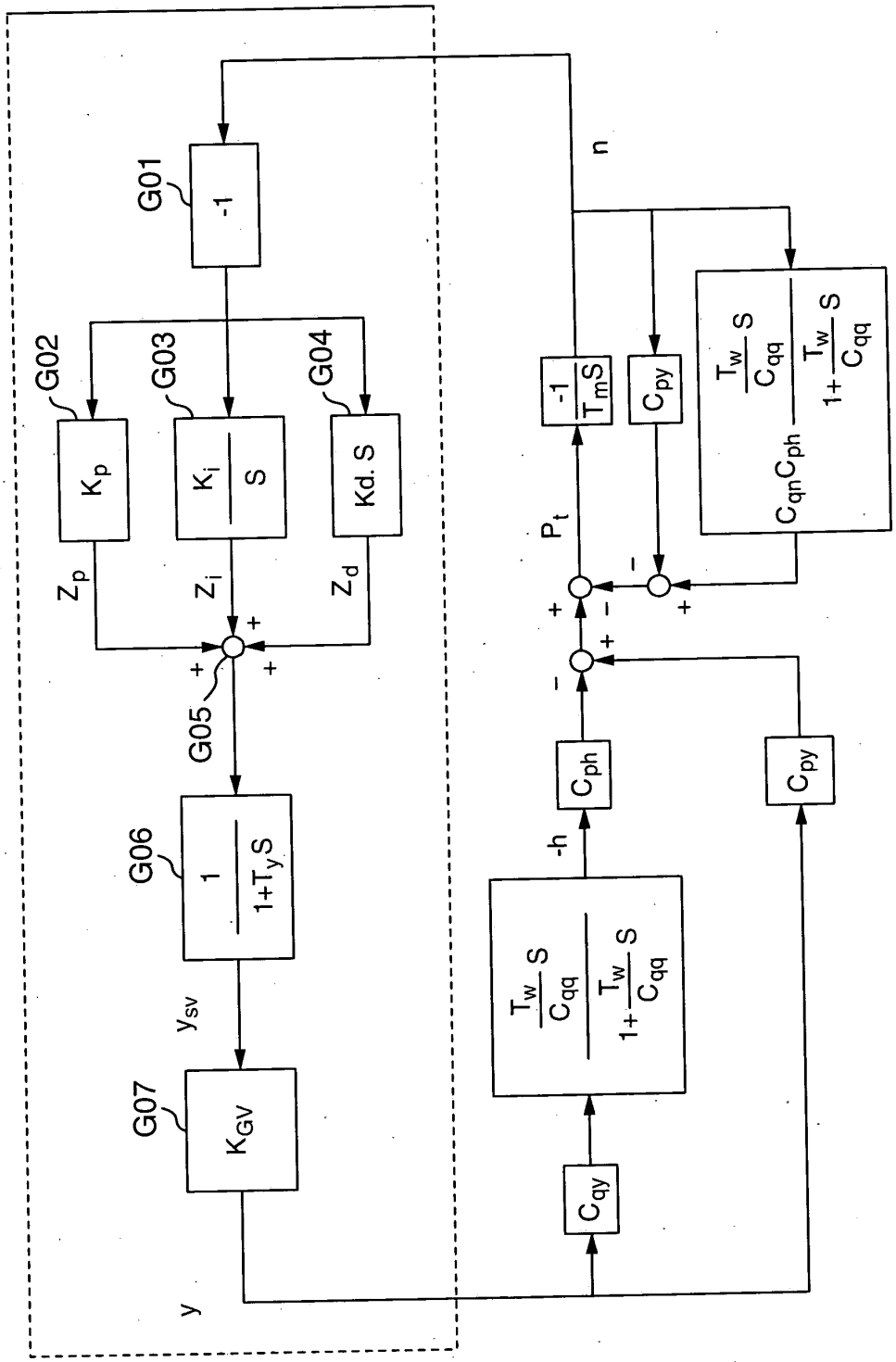

G01
-1
G02
K_p
G03
K_i / S
G04
Kd. S
Z_p
Z_i
Z_d
G05
G06
$\frac{1}{1+T_yS}$
y_{sv}
G07
K_{GV}
y
n
$\frac{-1}{T_mS}$
C_{py}
P_t
$\frac{\frac{T_w}{C_{qq}}S}{C_{qn}C_{ph}\ 1+\frac{T_w}{C_{qq}}S}$
C_{ph}
-h
$\frac{\frac{T_w}{C_{qq}}S}{1+\frac{T_w}{C_{qq}}S}$
C_{qy}
C_{py}

FIG.6

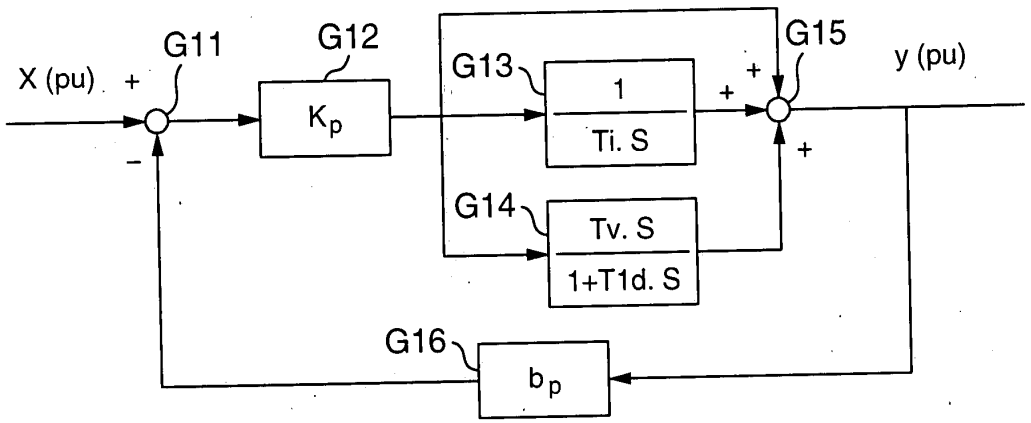

X (pu)
+
−
G11
G12
K_p
G13
1
Ti. S
G14
Tv. S
1+T1d. S
G15
+
+
+
y (pu)
G16
b_p

FIG.12

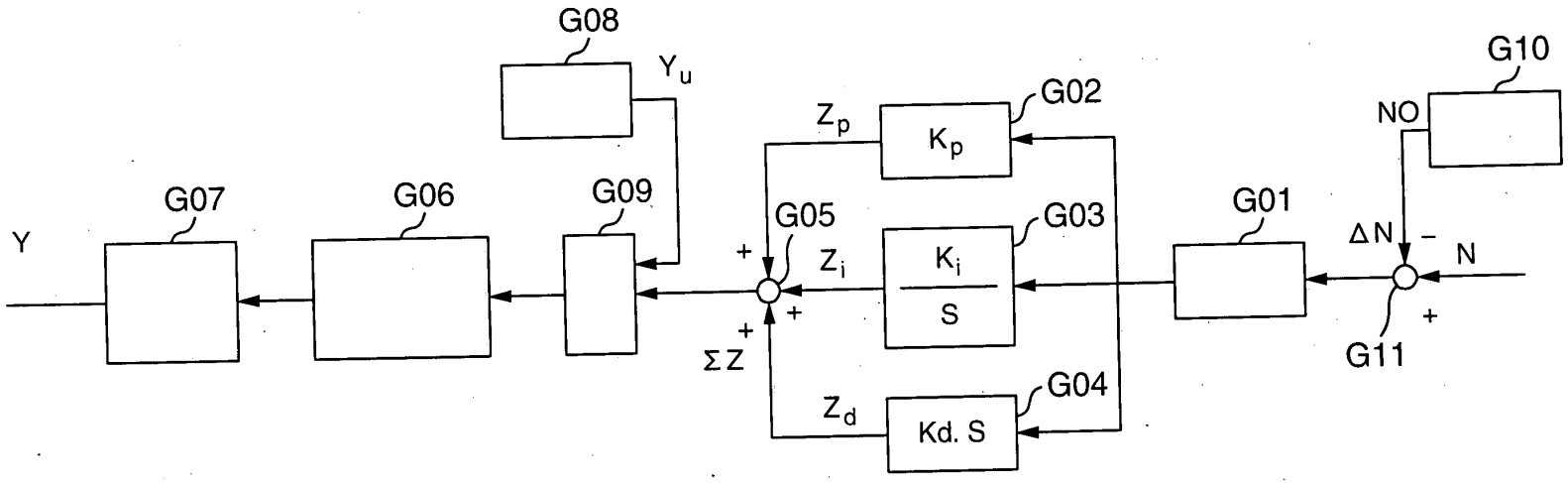
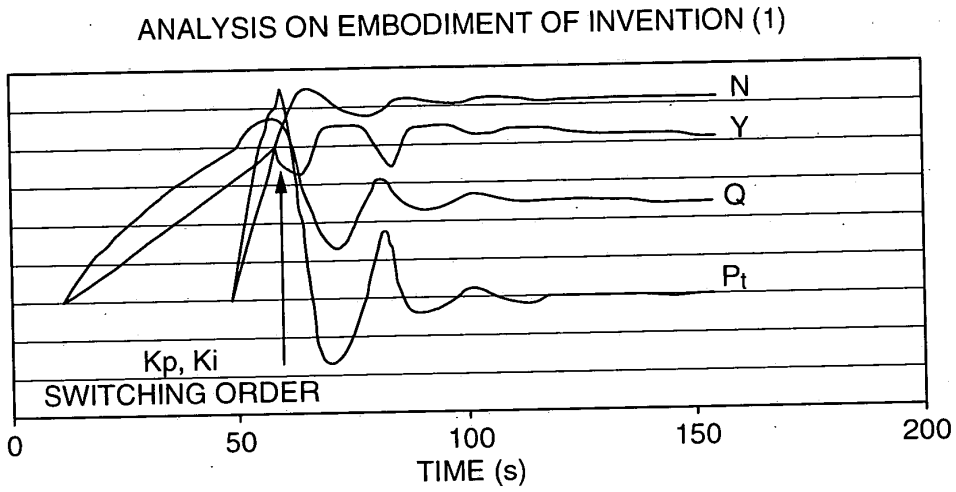

G08
Y_u
G10
NO
Z_p
K_p
G02
G07
G06
G09
G05
G03
G01
Y
+
Z_i
K_i
S
ΔN
−
N
+
+
+
ΣZ
G11
G04
Z_d
Kd. S

FIG.7


ANALYSIS ON EMBODIMENT OF INVENTION (1)
N
Y
Q
Pt
Kp, Ki
SWITCHING ORDER
0
50
100
150
200
TIME (s)

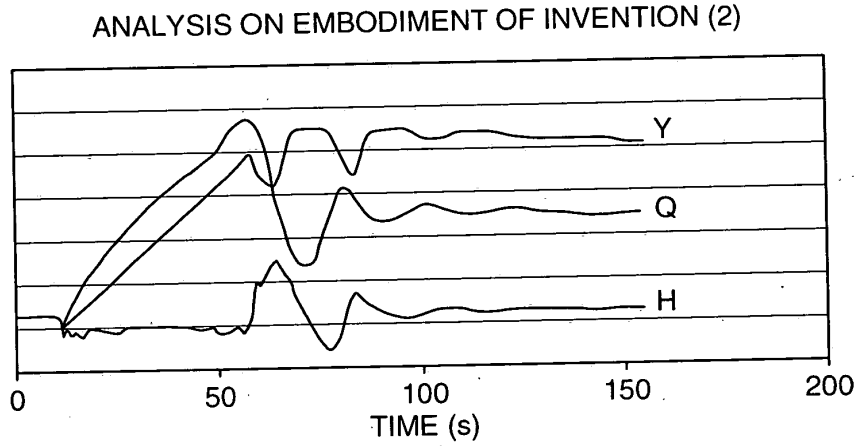
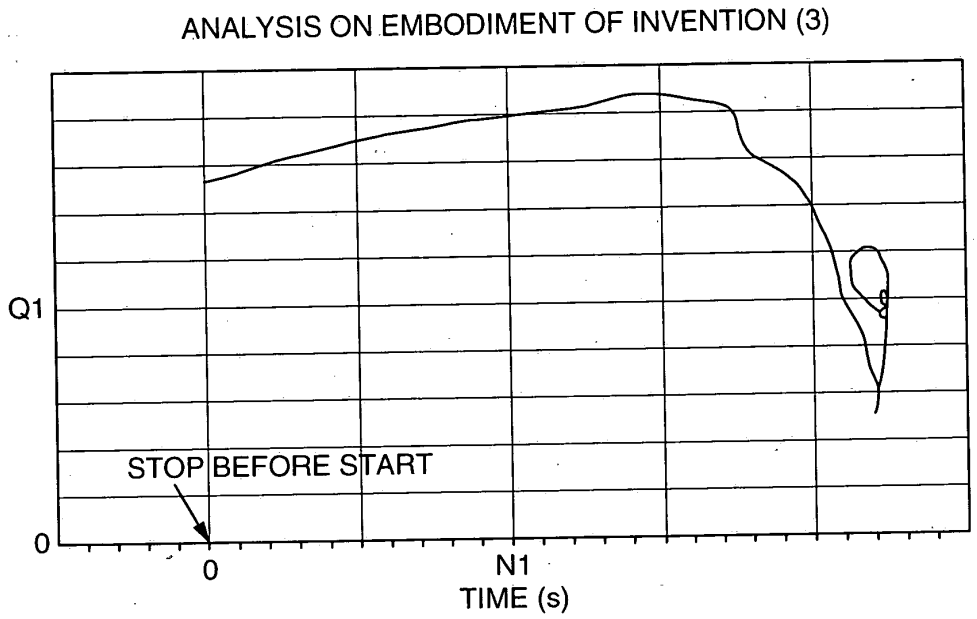

ANALYSIS ON EMBODIMENT OF INVENTION (2)
Y
Q
H
0
50
100
150
200
TIME (s)

FIG.8


ANALYSIS ON EMBODIMENT OF INVENTION (3)
Q1
STOP BEFORE START
0
0
N1
TIME (s)

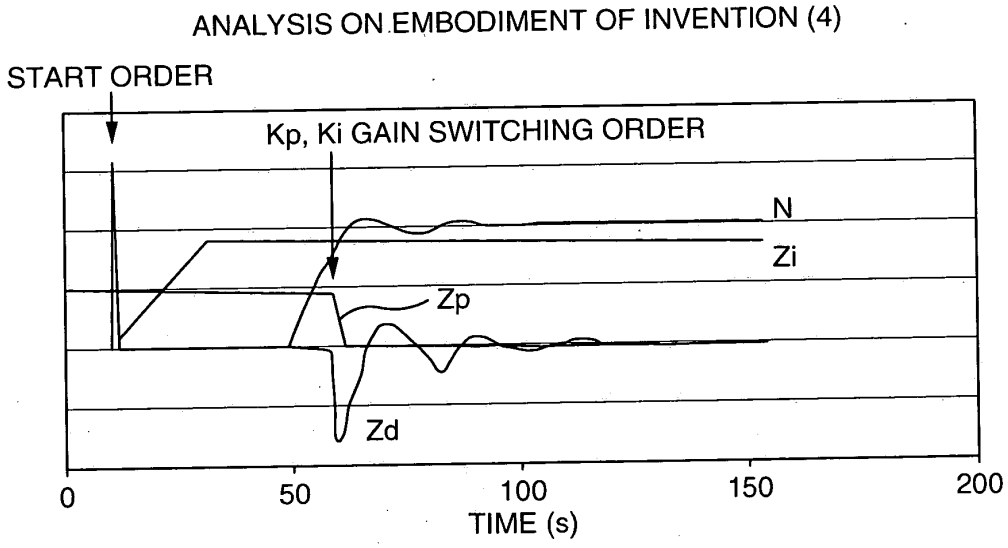

ANALYSIS ON EMBODIMENT OF INVENTION (4)
START ORDER
Kp, Ki GAIN SWITCHING ORDER
N
Zi
Zp
Zd
0
50
100
150
200
TIME (s)

FIG.9

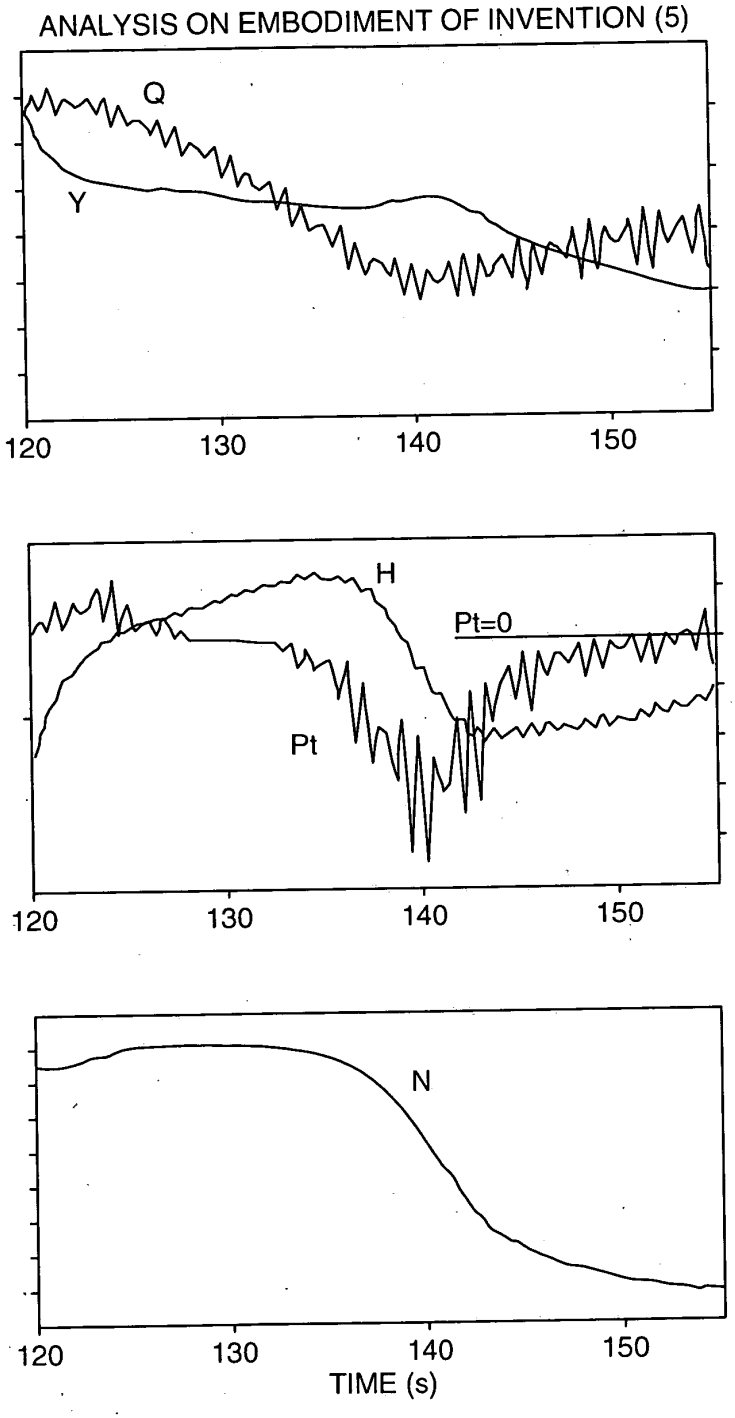

ANALYSIS ON EMBODIMENT OF INVENTION (5)
Q
Y
120
130
140
150
H
Pt=0
Pt
120
130
140
150
N
120
130
140
150
TIME (s)

FIG.10

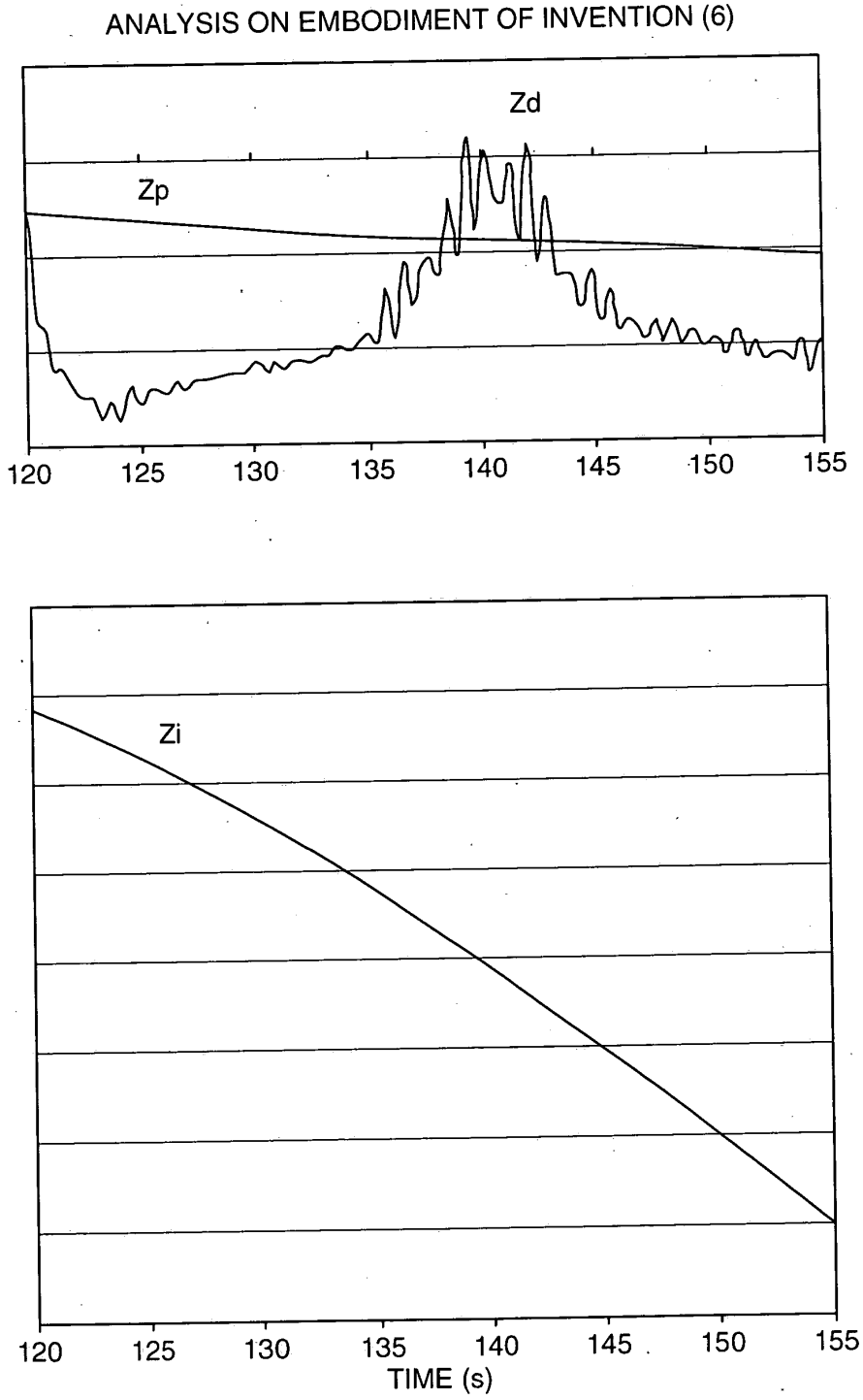
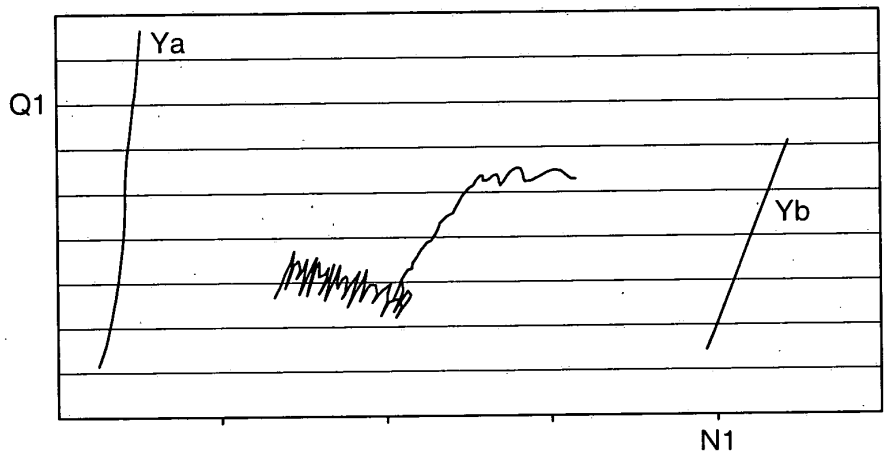

ANALYSIS ON EMBODIMENT OF INVENTION (6)
Zd
Zp
120
125
130
135
140
145
150
155
Zi
120
125
130
135
140
145
150
155
TIME (s)

FIG.11

ANALYSIS ON EMBODIMENT OF INVENTION (7)



ANALYSIS ON EMBODIMENT OF INVENTION (8)

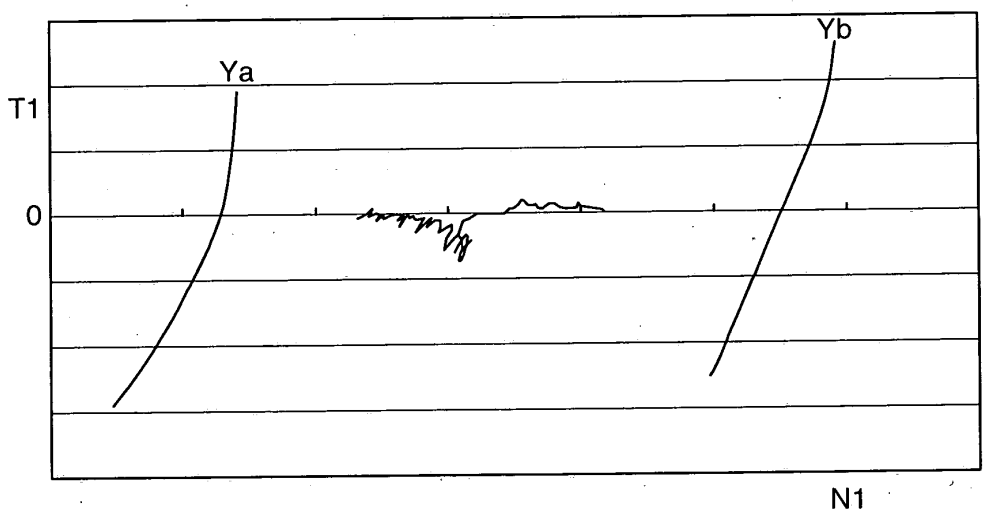


FIG.13

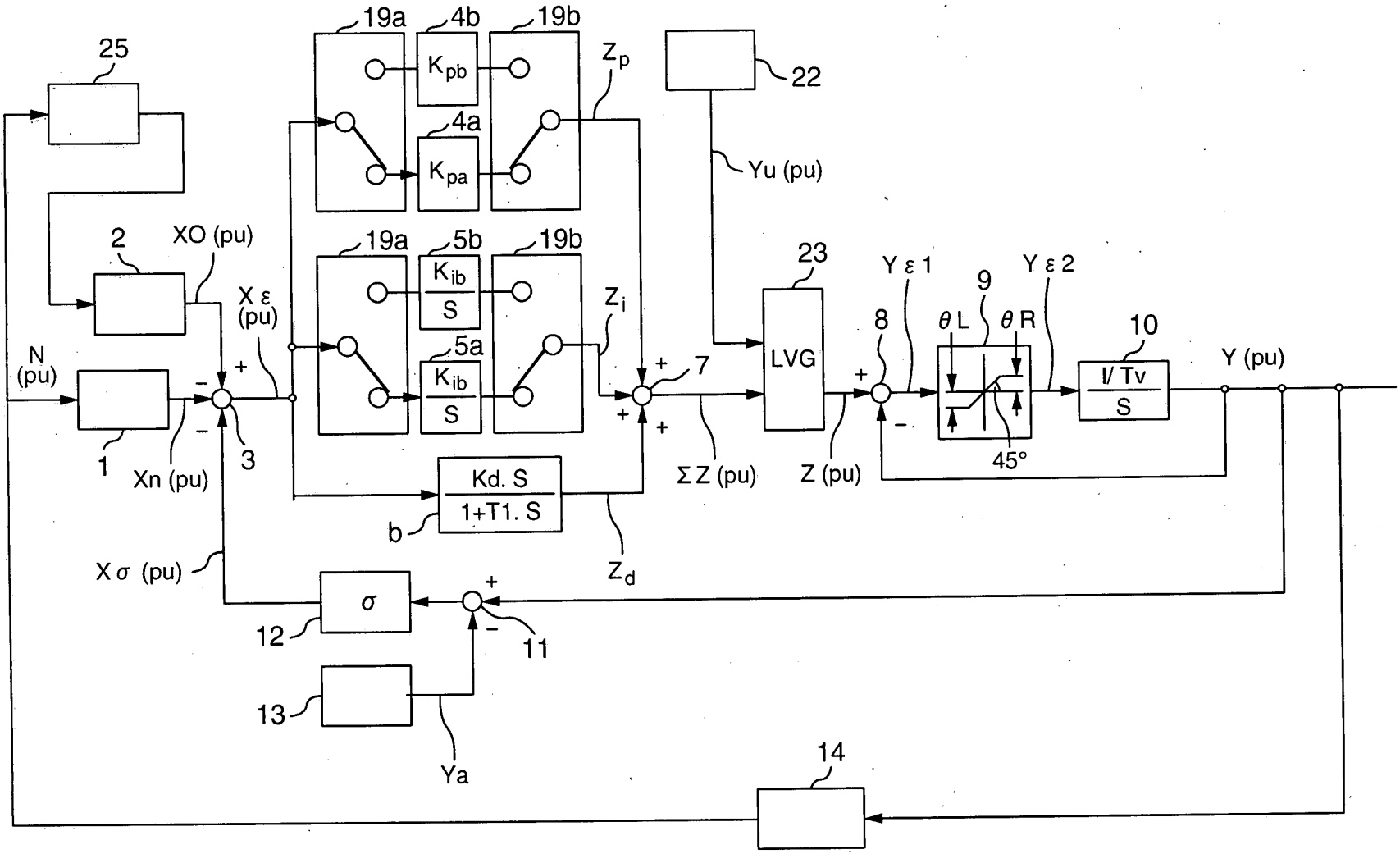
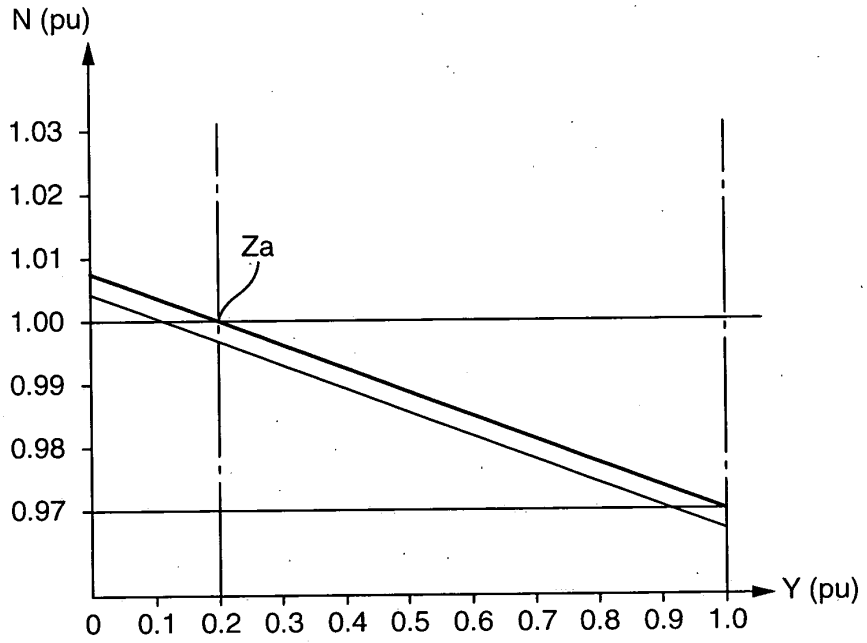

25
19a
4b
19b
K_{pb}
Z_p
22
4a
K_{pa}
Yu (pu)
2
XO (pu)
19a
5b
19b
K_{ib}
S
23
Y ε 1
9
Y ε 2
X ε (pu)
Z_i
8
θ L
θ R
10
N (pu)
5a
K_{ib}
S
7
LVG
Y (pu)
1
Xn (pu)
3
Kd. S
1+T1. S
b
ΣZ (pu)
Z (pu)
45°
I/ Tv
S
Z_d
X σ (pu)
σ
12
11
13
Ya
14

FIG.14

(a)


N (pu)
1.03
1.02
1.01
1.00
0.99
0.98
0.97
Za
Y (pu)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

(b)

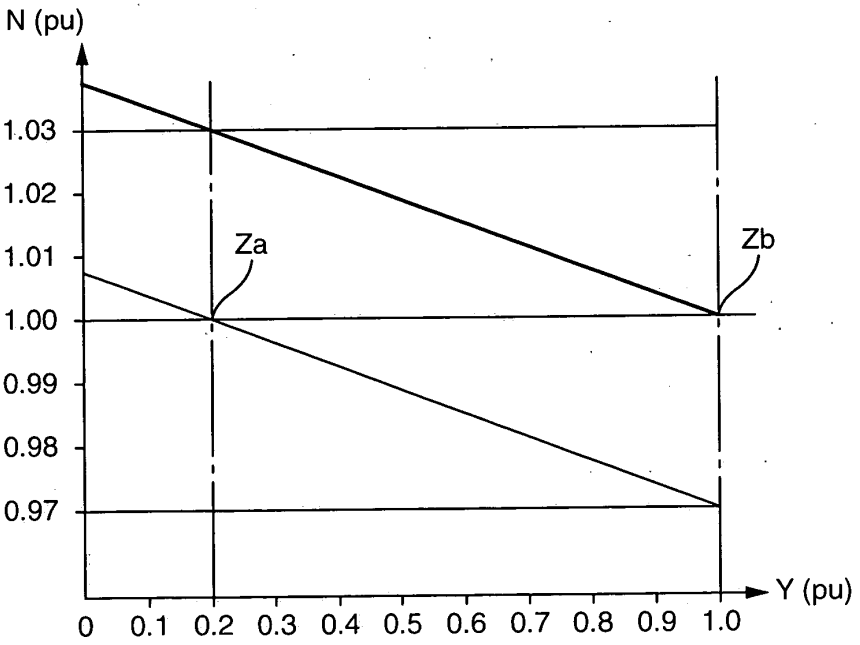
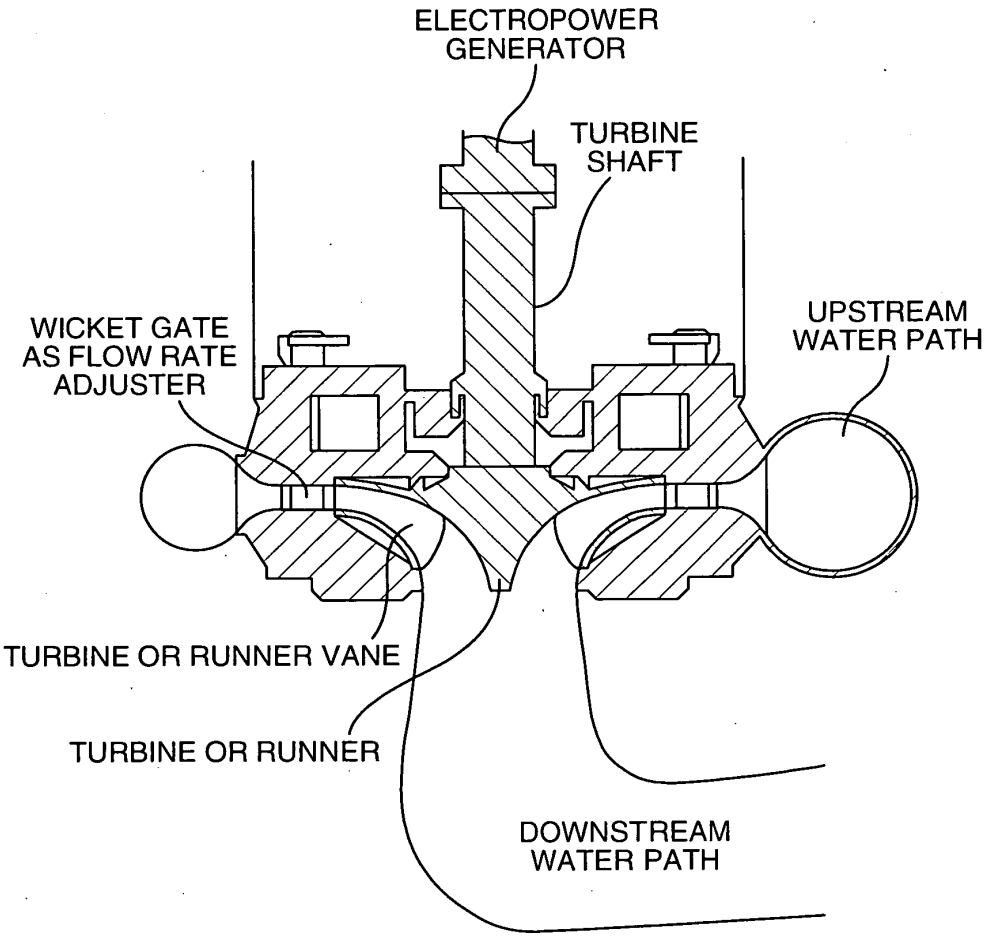

N (pu)
1.03
1.02
1.01
1.00
0.99
0.98
0.97
Za
Zb
Y (pu)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

FIG.15


ELECTROPOWER GENERATOR
TURBINE SHAFT
WICKET GATE AS FLOW RATE ADJUSTER
UPSTREAM WATER PATH
TURBINE OR RUNNER VANE
TURBINE OR RUNNER
DOWNSTREAM WATER PATH